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WRIGHT LABORATORY

ELECTRONIC MANUFACTURING PROCESS IMPROVEMENT (EMPI) FOR PRINTED WIRING ASSEMBLIES

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Program Task 1 Baseline Report

M. Read

TRW Military Electronics and Avionics Division
One Rancho Carmel
San Diego, CA 92198

April 1992

Final Report for Period August 1990 - August 1991

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Manufacturing Technology Directorate
Wright Laboratory
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433-6533

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18 Feb 92

ROBERT CROSS
Project Manager

DATE

14 Feb 92

DAVID McLAINE, Chief
Components Fabrication & Assembly Branch
Manufacturing Technology Directorate

DATE

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TRW Military Electronics and Avionics Division
One Rancho Carmel
San Diego, CA 92198

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Robert Cross (513) 255-2461
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13. ABSTRACT

This Task 1 Baseline report provides an outline of the work to be performed on the Electronics Manufacturing Process Improvement (EMPI) program and summarizes the results obtained independently by TRW from prior work. The report is divided into three primary sections: 1, Overall goals and objectives of the program, 2, Methodology used to guide performance of program, and 3, Results from TRW activity to-date.

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Printed Wiring Assemblies (PWAs), Electronic Manufacturing Process Improvement (EMPI), FPD Tinning, IR Reflow, Cleaning

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Table of Contents

Section | **Page**

List of Figures

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INTRODUCTION

The Task 1 Baseline report provides an outline of the work to be performed on the Electronics Manufacturing Process Improvement (EMPI) program and summarizes the results obtained independently by TRW from prior work. The report is divided into three primary sections: 1, Overall goals and objectives of the program, 2, Methodology used to guide performance of program, and 3, Results form TRW activity to date.

1. OVERALL OBJECTIVES AND GOALS

TRW's goal in performing the Electronic Manufacturing Process Improvement (EMPI) project is to identify, quantify (through process capability indices), and improve aspects of process control used in the surface mounted printed wiring board assembly flow. The resulting benefits of these improvements in the process will be identified and quantified to allow transition of the process improvement technology to others in the industry.

The EMPI project covers the basic printed wiring board assembly (PWBA) process which is represented by Figure 1. The individual factory processes, or workcells, covered by the study are indicated by shading and are grouped into five subtasks: (1) material deposition which includes solder paste and component placement; (2) Fine Pitched Device (FPD) leaded component forming; (3) FPD and ceramic leadless component tinning; (4) reflow, and (5) cleaning which includes component standoff application and solvent cleaning The process equipment used to perform the project are described in Figures 2 through 6.

The project concerns all of the potentially significant variables that are controlled and determined outside of the workcell itself (intercell variables). These include the result of any external process equipment variables or manually-controlled variables that are impossible to monitor or control at the workcell but still contribute directly to the workcell yield. These variables originate as outputs from other workcells, either workcells within the scope of the study itself, or possible, from other workcells not identified such as from a vendor. An example of an intercell variable would be the PWB thickness, which is controlled by the PWB fabricator and still directly influences the reflow process yield by introducing variations in the heat required to reflow the PWB due to varying PWB weight.

2. METHODOLOGY

The measuring tools selected to understand and quantify the level of process control are the Process Capability Indices, Cp and Cpk. These indices provide a quick measure of the degree of "robustness" or "safety margin" existing within a process, and, therefore, are a key indicator of the ability to obtain and maintain 100 percent yields. Each process has multiple Cpk and Cp indices, one pair for each requirements or response within the process. The overall individual process Cpk/Cp combination may be said to be simply the smallest of all of the Cpks determined for the process since it most frequently will be the factor limiting yield.

The project consists of six basic steps that are repeated for each process area studied. The details and assumptions used in performing each step of the project are discussed below.

2.1 STEP 1.

The first step in the study identifies the process flow to be studied. The simplified flow used to illustrate the scope of they study (Figure 1) was obtained from a more detailed process flow showing all potential routes that an assembly might take. These workcells represent the "core" of the PWBA assembly process.

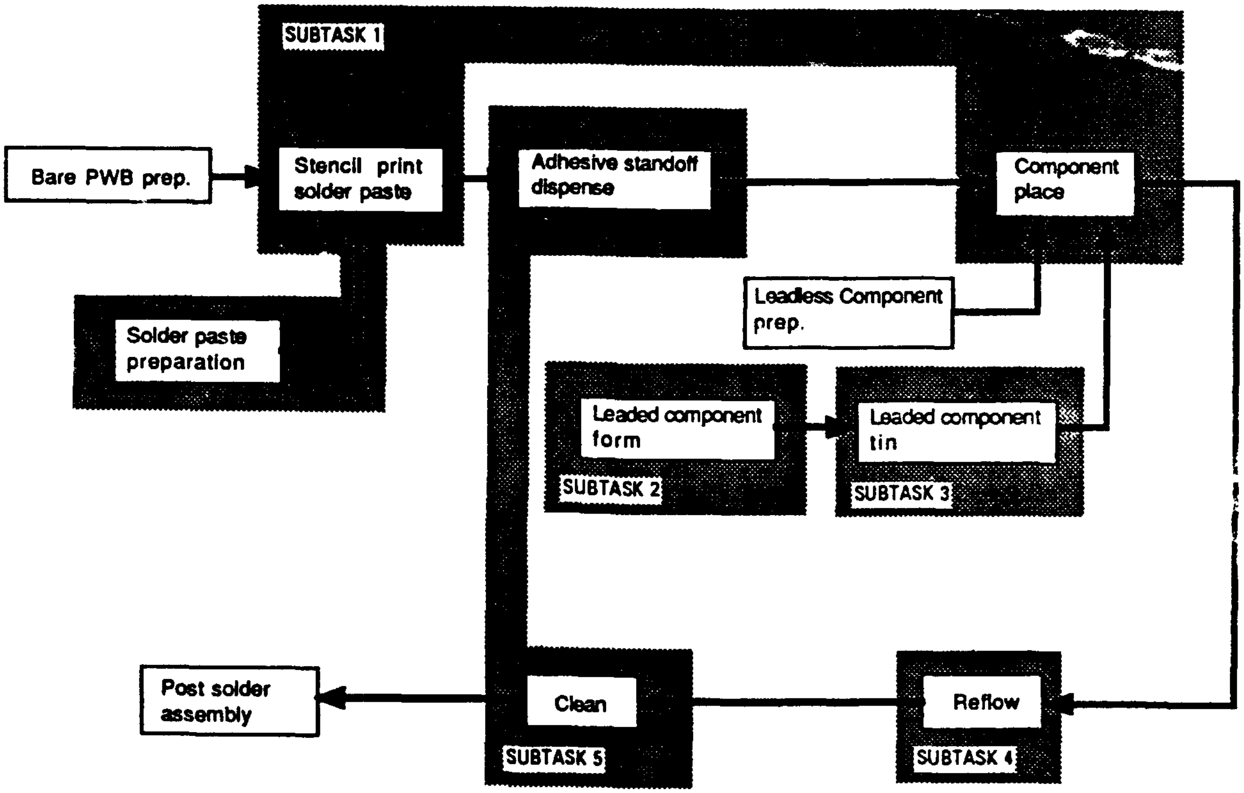


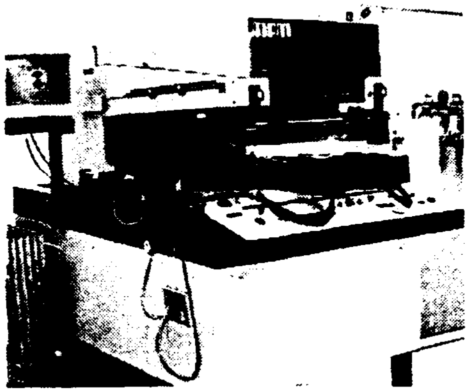
Figure 1. EMPI Project and Process Flow

Solder Paste Control and Application

Work Station Objective: Apply a controlled and repeatable volume of solder paste on selected metal pads of a PWB with minimal setup labor and skill

Equipment/Features:

Vision-assist stencil printing system (MPM AP-24)
— Fiducial alignment of PWBs (+/0.0005)
— 24-inch screen frame size
— Workcell control/logging to/from Microvax
Solder paste viscometer (Austin American)
Constant solder temperature bath (Brookfield)
Solder tack tester (Austin American)
Stencil cleaning system (Tooltronics)
Adhesive dot dispenser (Creative Automation ADM-1214)
Solder paste profile system (Cyber Optics Micro-Scan)
LCC solder tinning station (Exselect)



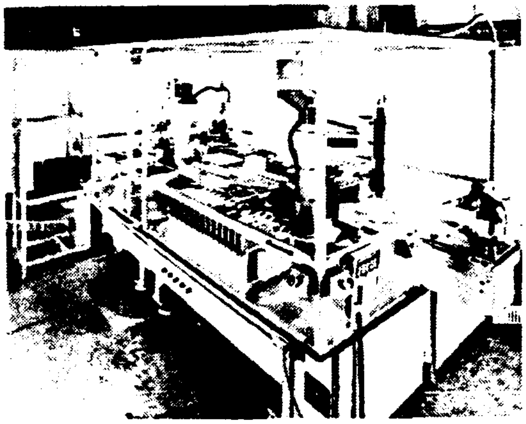
Process Control

Vision-assist alignment
Downloaded printing parameters
Paste viscosity control charts
Paste tackiness control charts
Paste height control charts
LCC pre-tin control charts

Setup time:
5 min/lot changeover
Cycle time: 1 min cycle time

SMT Robotic Component Placement

Work Station Objective: A flexible means to accurately and repeatedly place components onto PWB land patterns. Robotic workstation focused on FPD/leaded device preparation and placement.



Equipment/Features:

Flexible robotic workstation (Gelzer Systems)
- Two-arm adept based system (SCARA)
- Prep stage to place stage FPD delivery system
- Vision system for placement (+/-0.001)
- Workcell control/logging to/from Microvax

Process Control

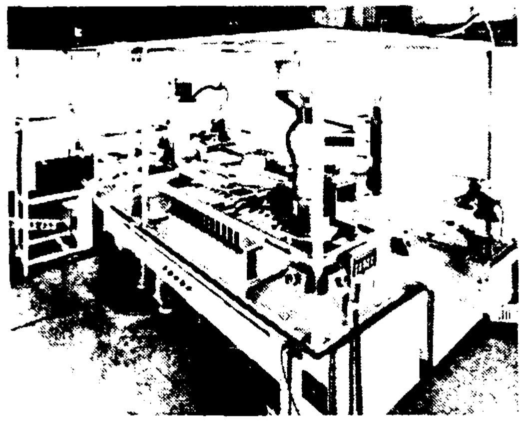
Vision system: Alignment and inspection
CAD downloaded pick/place parameters
Component placement control charts
End effector tactile placement sensors (robot)

Setup time:
5-10 min/lot character
Cycle time:
17 sec FPD place

Figure 2. Subtask 1: Material Deposition - Equipment Description

SMT Robotic Component Forming

Work Station Objective: A flexible means to accurately and repeatedly place components onto PWB land patterns. Robotic workstation focused on FPD/leaded device prepara' nd placement.



Equipment/Features:
Flexible robotic workstation (Gelzer Systems)
- Two-arm adept based system (SCARA)
- FPD trimming, forming
- Workcell control/logging to/from Microvax
- Component standoff height repeatedly within 1 mil of set point

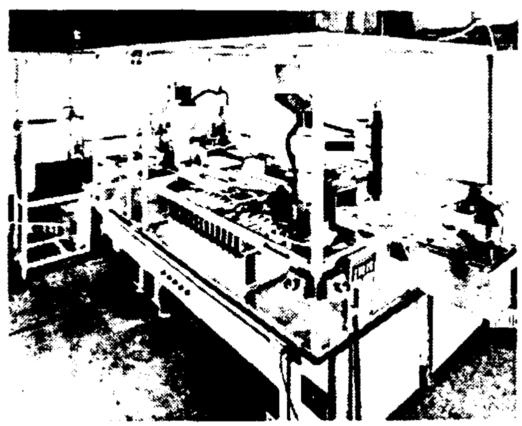
Process Control
Electronically controlled floating anvil
Proximity sensing assures accurate part placement into the trim and form stages

Setup time:
5-10 min/lot character
Cycle time:

Figure 3. Subtask 2: FPD Forming - Equipment Description

SMT Robotic Component Tinning

Work Station Objective: Robotic workstation focused on FPD/leaded device preparation and placement.



Equipment/Features:
Flexible robotic workstation (Gelzer Systems)
- Two-arm adept based system (SCARA)
- FPD fluxing (when applicable), tinning and cleaning
- Five-axis arm for part presentation at any orientation
- Workcell control/logging to/from Microvax

Process Control
Vision system: Alignment and inspection
CAD downloaded tinning and inspection parameters
Flux density controller (robot)
Solder tin speed and depth control (robot)
Preheat stage for thermal shock prevention
Air knife capabilit y for solder bridge removal

Setup time:
5-10 min/lot character
Cycle time:

Figure 4. Subtask 3: Component Tinning - Equipment Description

Solder Paste Reflow Technologies

TRW

Work Station Objective: Reflow PWBAs to form acceptable solder joints from solder paste deposits without damaging components or PWBs with minimal setup labor and skill

Equipment/Features:

In-line infrared reflow station (Vitronics 722)
- Convection (60%)/IR (40%) - heating
- 20-panel, 10-zone, nitrogen purge
- Workcell control/logging to/from Microvax

Vapor phase soldering station (HTC 18-26)
Hot bar reflow soldering station (Hughes TCW 119)
Strip chart temperature recorder (Omega)
Temperature profiler (Mole-ECD Systems)

Process Control

Continuous process monitor/control/alarm status
Downloaded process parameters

Setup time:
5-10 min/lot character
Cycle time:
3-5 min cycle time

Figure 5. Subtask 4: Reflow - Equipment Description

Component Standoff:

This portion of the experiments will be performed at a PWB vendor due to the change in standoff process from adhesive dots to dry film features.

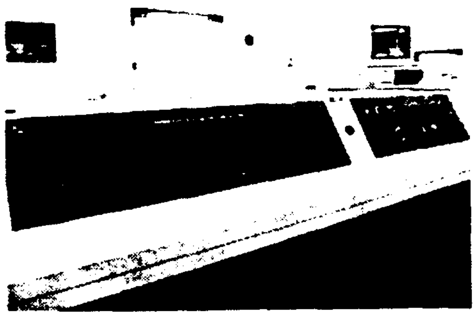
PWBA Solvent Cleaning System

Work Station Objective: Clean PWBAs of flux residues left from paste deposit/reflow systems with minimal setup and direct labor.

Equipment/Features:

In-line solvent cleaning station (B/B-CBL-18)
- Heated, immersion and high pressure spray
- Workcell control/logging to/from Microvax
- Blakeslee-Solv 404 solvent (chlorinated)

Ionic contamination tester (Westek-Icom 4000)
- Heated and sprayed solvent SMT penetration



Process Control

Continuous process monitor/control/alarm status
Downloaded process parameters
Cleanliness verification control charts

Setup time:
No lot changeover
Cycle time: 6 min cycle time

Figure 6. Subtask 5: Cleaning- Equipment Description

2.2 STEP 2

Step 2 in the project identifies critical process responses, or outputs, and all suspected variables or inputs that influence them. This is best accomplished at a brainstorming session where all experienced study contributors are encouraged to participate. At this point, it is not important to match a variable to a given response, only to identify as many meaningful variables and responses as possible. All of the important responses must be identified, since it is impossible to identify and study defects that are not defined. It is important to be thorough with the variables as well, but if a major variable is overlooked, the statistical techniques used in the data reduction step will at least identify the presence of the "missing" variable(s). The responses and variables are identified on a "fishbone chart" for convenience and for help with identifying sub-layers of variables and variable groupings. The initial selection of variables included in the EMPI project are indicated by the shading of the variables in the fishbone charts of Figures 7 through 11.

2.3 STEP 3

Once the variables and responses are identified, Step 3 quantifies them and establishes the measurement method used. The values of the responses are taken from either a formal deliverable requirement (e.g., MIL-STD-2000) or an internally developed and controlled requirement (e.g., solder paste thickness). The formal specification limits are easiest to quantify. Usually the applicable requirement document lists the specification directly. Where this is not the case, or where the requirement is internally developed, experimentation may be required to define the limits of the specification. This process may be involved and subject to revision or iteration if the specification is part of a system where the goal is to share a tolerance budget equally among several processes. The variable limits usually require some experimentation to define. Even in the case of process equipment where the machine capability is "advertised" by the manufacturer, the actual variability limits of the machine must be identified. The simple experiments required to define the machine variability not only will uncover any misrepresentation, but may uncover other critical, overlooked process variables. Once the data is obtained, the specifications and variables are listed as groups and the numerical value for each response limit and variable limit is listed with the respective item.

It is during this step that the measurement techniques used for data collection are identified and developed. The goal is to maintain an order of magnitude (x10) margin between the data values and the measurement precision. This goal is difficult to maintain in all circumstances, especially in cases where the measured response is being matched to an arbitrary scale such as "shiny/matte/dull."

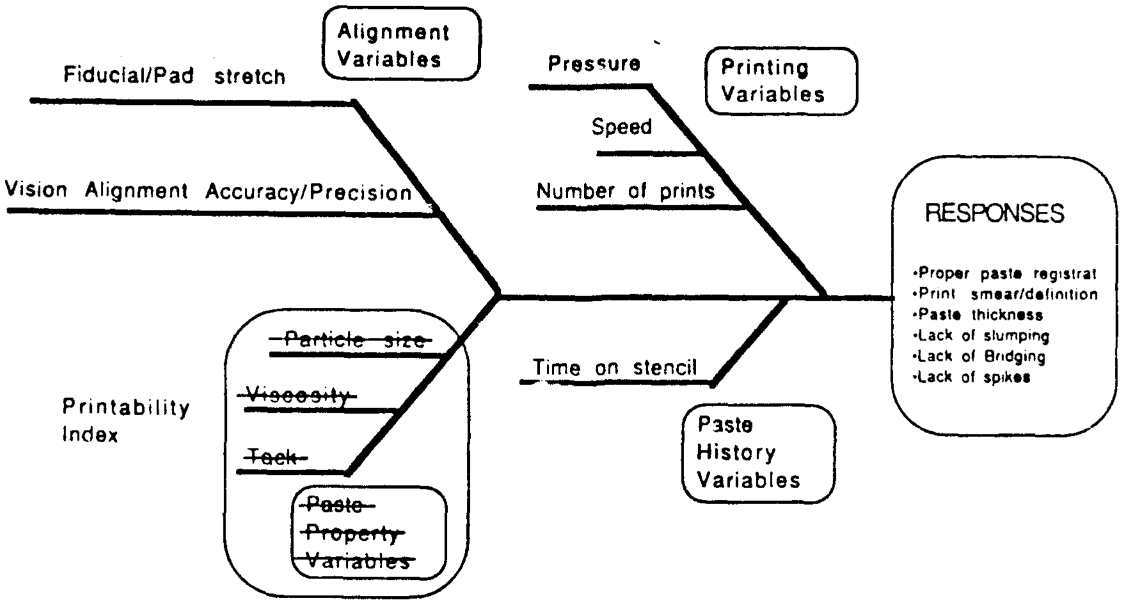
2.4 STEP 4

Step 4 in the project establishes the relationships between the specifications and the variables. This an important precursor to the experimental design process and identifies the contents of each performed experiment. This relationship is determined by establishing an "experimental plan/results" matrix with the responses listed in a column along the left edge with the variables in a row at the top. The matrix is completed by filling in each cell where a response row intersects the column of a variable that is suspected to influence that response. This is best performed at a brainstorming session involving those who generated the original "fishbone" lists of responses and variables. Once the matrix is completed, each row of the matrix becomes the contents of an experiment. The response to be measured is listed, as well as the variables to be tested. This becomes an important reference during experimental design. Note that multiple responses may be explored with one experiment as long as the responses can be measured independently.

2.5 STEP 5

Step 5 establishes the exact experimental technique to be used with the variables, runs the experiment to obtain the data, and reduces the data to calculate Cp and percent contribution of variability. The experimental techniques used to determine the variable/response relationships vary, depending on the number and nature of the variable. If the number of variables is limited to three or four, and variable

SOLDER PASTE DEPOSITION FISHBONE CHART



FPD COMPONENT PLACEMENT FISHBONE CHART

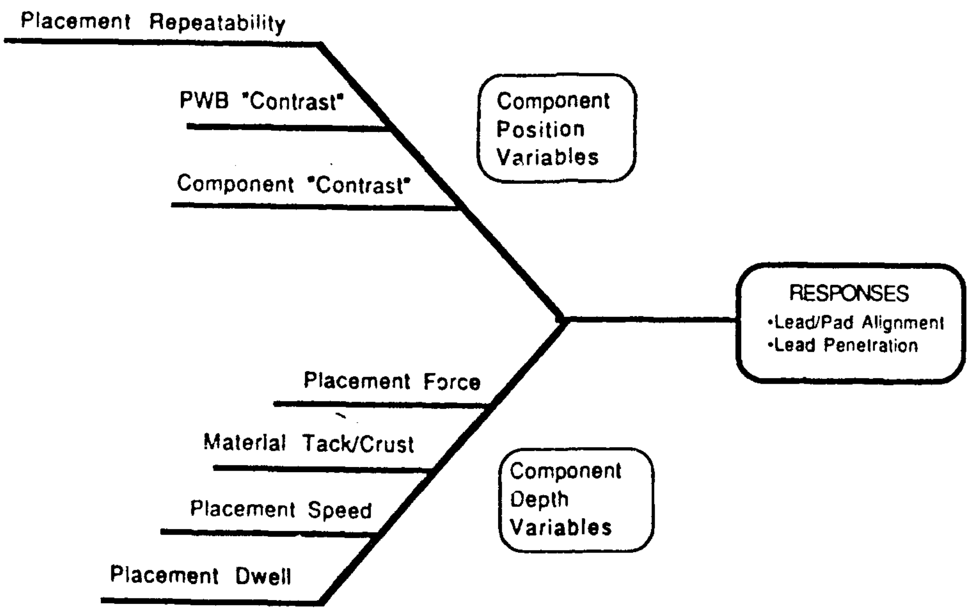


Figure 7. Subtask 1: Material Deposition

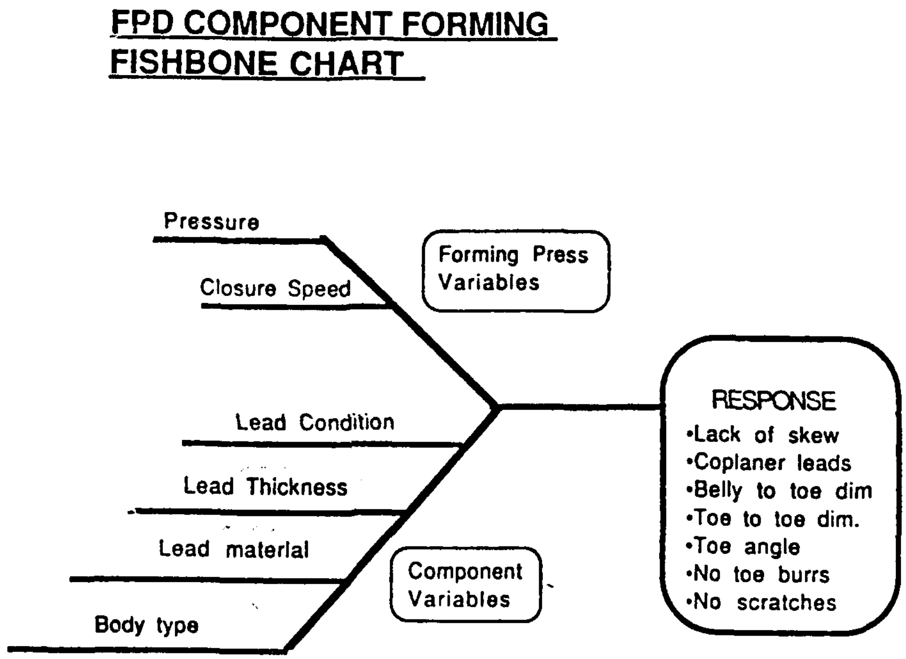


Figure 8. Subtask 2: Component Forming

FINE PITCH DEVICE TINNING FISHBONE CHART

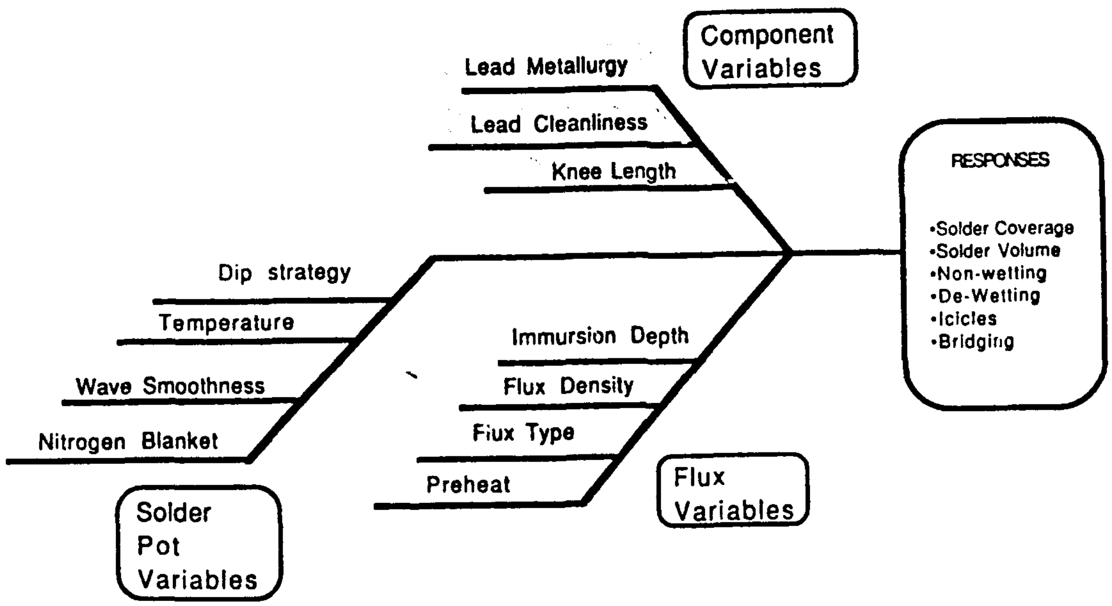


Figure 9. Subtask 3: Component Tinning

FINE PITCH DEVICE IR REFLOW SOLDERING FISHBONE CHART

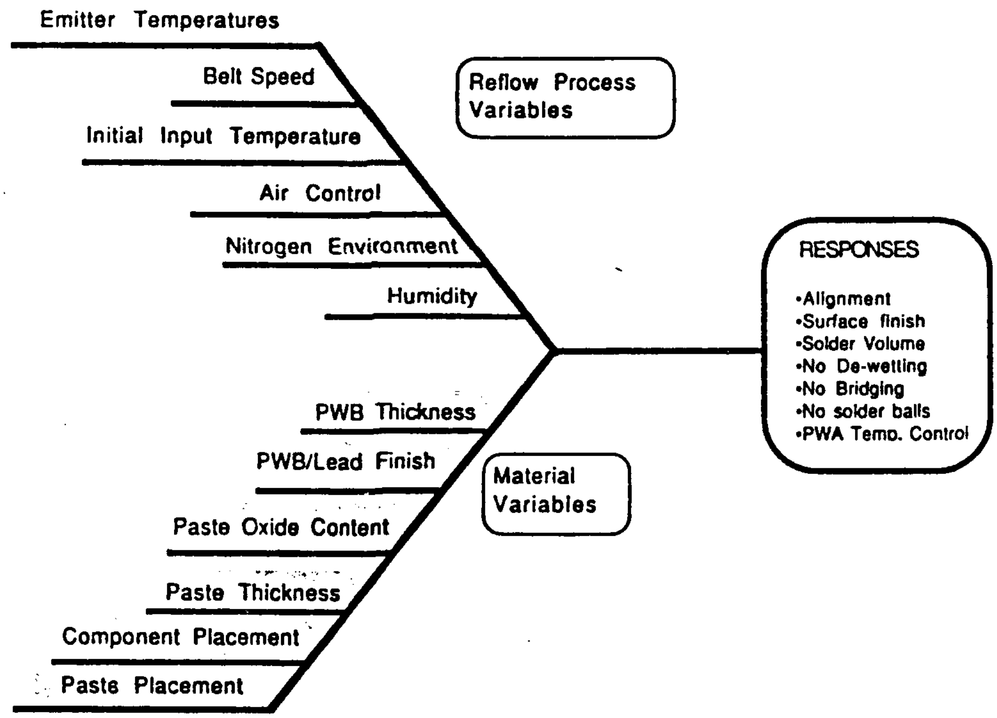
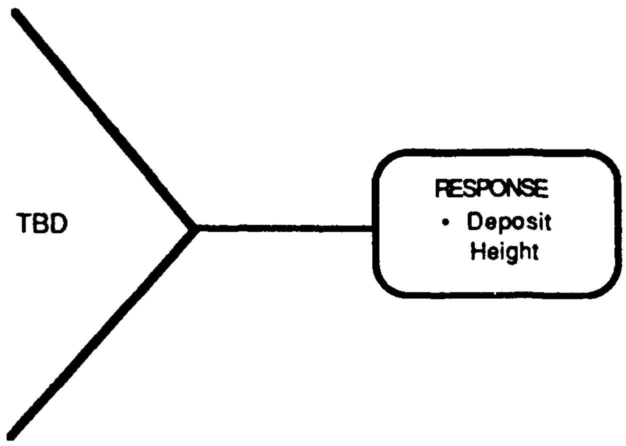


Figure 10. Subtask 4: Fine Pitch Device IR Reflow Soldering

DRY FILM SOLDER MASK STANDOFF APPLICATION FISHBONE CHART



PWBA SOLVENT CLEANING FISHBONE CHART

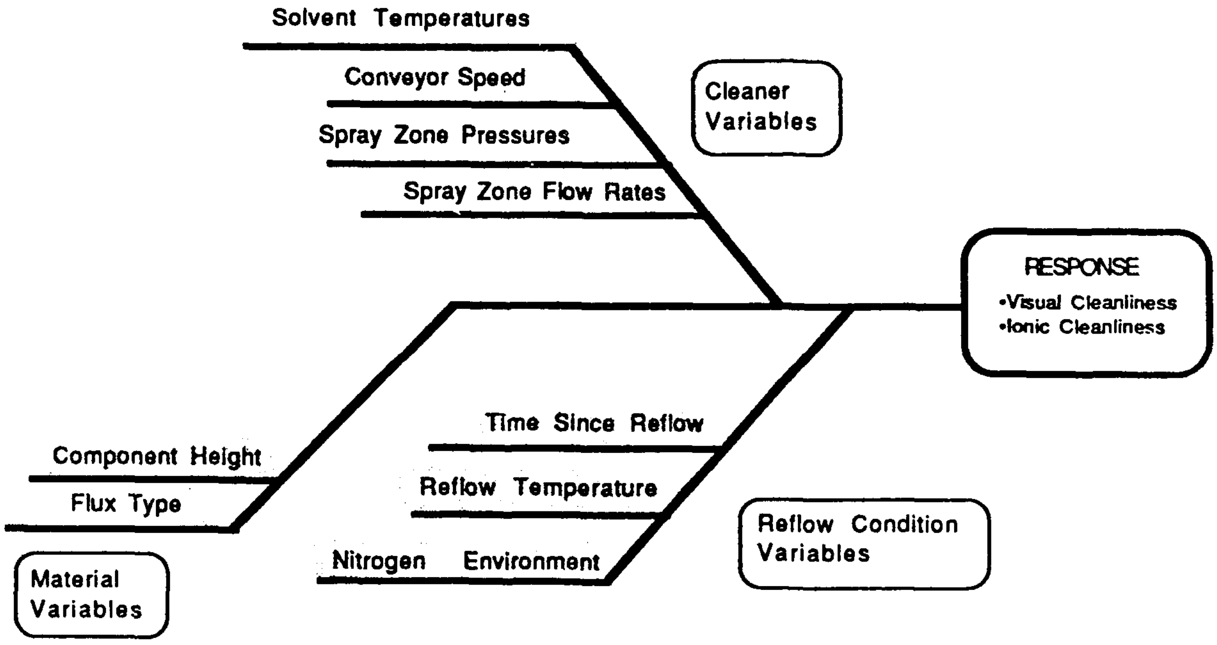


Figure 11. Subtask 5: Cleaning

interaction is suspected, then a full factorial experiment may be required. If, however, the number of variables is five or greater, and variable interaction is not suspected, then fractional factorial design such as a Taguchi style L8 or L16 experiment may be employed.

Once the experimental design is selected, the experimental plan/result matrix obtained in Step 4 is consulted to obtain the starting information for the detailed experiment matrix. For rows of the matrix, each representing one experiment, variable columns are removed and transferred to the detailed experiment matrix's; separate columns are established and labeled with the corresponding response items to allow collection of the experimental data. Since the overall goal of the experiment is to obtain the maximum response due to the low-to-high transition in variables, all of the experiments are based on a two-level (high, low) design. The detailed experiment matrix, therefore, can be represented by a classic "plus/minus" matrix with the response to be observed and the variables to be exercised heading the columns with the experiment run numbers heading the rows. The "plus/minus" matrix thus gives the exact recipe for each experiment run.

With the detailed experimental plan established, each experiment run is performed by forcing each variable to its high or low value ,depending on the plus or minus symbol located in the variables' respective column for the particular run; the resulting response data is logged. Since the entire experiment depends on forcing variables to predetermined values, and many variables are unable to be predicted in advance, some experimental runs require that alternate techniques be used to perform the experiment. An example would be component placement, where the experimental design requires that components be placed +0.0025 inch away from nominal. Since the precision of the placement equipment is ±0.0025 inch and, therefore, the exact placement is undetermined within this range, it is more expeditious to place the component manually with a placement aid, e.g., milling machine with x/y table and digital readout. This technique allows experiments representing the extreme limits of equipment capability to be performed at will.

The experiments are replicated three times to obtain the most information about "hidden" variables as possible. The first set of runs, or baseline runs, is conducted as described by the detailed experimental plan and is used to obtain an initial rough look. The second set of runs, error detection runs, are conducted as described by the detailed experimental plan, are compared with the baseline runs to determine the experimental error, and thus refine the understanding obtained from the first set of runs. This set of runs may not be required if the experimental design allows the inclusion of an error term with the variables directly. The third set of runs, or reflection runs, use the inverse of the experimental plan and allow one last change to identify any hidden variables or variable interactions.

Once the data is obtained, it is reduced to obtain the Cpk and percent contribution of variability numbers. The calculation of percent contribution of variability is obtained form ANOVA (ANalysis Of VAriance) and can be found in most statistical references. It is used in this study to give an indication of the probability of an unknown variable or interaction effect expressing itself.

The sixth and final step in the project implements the results obtained, Processes that need to be improved, based on the results of the project, will be improved and verified. The resulting controls that are identified will be implemented. Many of the variable limits are actually monitored in a closed loop fashion by the process equipment itself, and after being characterized by the study, need monitoring only as part of a preventive maintenance plan. Other variables impossible to control with currently available technology need to be manually tracked (actually manually entered into a computer data base such as (QMS) in more of a classical SPC manner. Once all of the variable controls have been implemented into factory documentation, ongoing yields should be monitored for changes due either to unknown variables or process problems resulting from equipment failures.

3. PRIOR RESULTS SUMMARY

The following represents a summary of the process capability study activity performed to date. The results are presented in three sections; a brief summary for each process describing significant Cpks and

variables, a brief outline of the most critical processes/variables which need the most improvement, and a list of process and experimental "lessons learned".

3.1 PROCESS SUMMARIES

Subtask 1: Material Deposition:

Solder Paste Deposition: There are no formal MIL-STD requirements for past definition, so internal guidelines and workmanship standards were used as specifications. The current Cpk's range form a low of -0.35 to a high of 12. The most probable variable for improvement is paste type and/or vendor, since little effect was noticed during the manipulation of the variables.

The registration of the paste to the pad is one of the most critical process responses (especially when printing fine pitch deposits) and is one of the most robust paste deposition Cp's, at 1.2 to 1.5. Adjustments to the way that the stencil contracts the substrate should improve this Cpk to a solid 1.5.

The definition of the current printing process leaves much to be desired, with poor print quality after only three prints. The resulting CP's reflects this fact, ranging form -0.35 to 0.46. There are no significant variables that can improve this very much, and an alternate paste is the most probable place to look for improvement.

Component Placement: The placement operation has no direct MIL-STD requirements, although the placement accuracy directly influences the resulting component position after reflow which is covered by the standard. The placement registration is potentially in trouble with a Cpk of 0.7. The normal "dry" (no solder paste placement accuracy is ±0.002 with an additional ±0.001 inch misregistration due to the skidding of the component when placed on the solder paster. This compares with an allowable misregistration of ±0.002 inch. It is suspected that the reflow process will "adjust" the part location by several mils, allowing the final part position to be improved. This will be investigated as part of the EMPI project. The penetration CP is less than one due to the influence of lead coplanarity. The coplanarity cannot be tightened significantly, so the possibility of deeper average penetration will be explored.

3.1.1 Subtask 2: FPD Forming

The forming operation is in good shape with the exception of the lead skew response (one of two formal MIL-STD-2000 requirements). The Cpk's range form 0.7 to 14+. The largest problem seen with the lead skew appears on leads that were "pre-bent" to represent the worst case condition from an off-line component prep operation. This needs further review.

3.1.2 Subtask 3: FPD Tinning

The tinning process has MIL-STD requirements that cover the height that solder is allowed to wick up the component lead and the minimum coverage areas. These responses are generally in good shape. The solder volume response is robust, with a Cpk of 4. The solder coverage Cpk is less than 1, but when only including parts that were tinned using nitrogen, the Cpk rises to 1. The presence or absence of nitrogen appears to bean overwhelming variable, improving all aspects of tinning. Additional work must be performed to establish the nitrogen-assisted coverage Cpk.

3.1.3 Subtask 4: IR Reflow

The reflow process has several MIL-STD-2000 requirements. The reflow operation Cpk's range is from 0.7 to 4. Several aspects of the processes are in relatively good control (joint finish and temperature repeatability) while some of the more material-dependent responses (solder balling and dewetting) are poorly controlled. In many ways, the reflow process is the general "catch all" of the assembly process,

especially where metallurgy is concerned. The poor showing in the dewetting response does not appear to be a function of the reflow process itself as much as a reflection of the incoming material state. These variables will be investigated within the EMPI portion of the study. The excessive solder balling requires further review. Higher baseline temperatures and standoffs (they were omitted during the experiment) will be evaluated.

Among the joint finish and temperature response that are more clearly a function of the oven, the Cpk's are above 1 in most cases. One of the most important variables of the finish response is the presence of nitrogen. This is confirmed somewhat by the robotic FPD tinning results, as well, and seems to be significant in cleaning. The most important variable of the temperature response is the Emitter temperature variation, representing half of the allowable temperature variation.

3.1.4 Subtask 5: Cleaning

Component Standoff: There are no formal MIL-STD requirements for component standoffs, but it has been determined that a 0.004-0.005 inch high standoff is required for proper cleaning. The original component standoff approach involves using adhesive dots under components to create a cleaning gap. This approach has been determined to be ineffective, with excessive dot-to-dot variation even within a given PWB. This study has been redirected to incorporate standoffs created from dry film solder mask deposits.

Solvent Cleaning. The cleaning process has two MIL-STD-2000 requirements via the MIL-P-28809 cleaning specification. This operation has Cpk's that are less than 1. They range from 0.3 to 2.1. These Cpk's tend to misrepresent the process capability due to experimental limitations. The actual cleaning Cpk's are below 1.0.

None of the variables within the cleaner itself (solvent temperature, spray pressure, etc.) were found to significantly affect the cleanliness of the PWA's. It appears that the reflow conditions, specifically the use of nitrogen during reflow, or the use of vapor phase reflow are the most significant process variables. Clearly, the results to date indicate that the process must be changed (not controlled tighter). Alternative reflow techniques, flux formulations, and paste vendors are currently being evaluated.

3.2 CRITICAL PROCESS IMPROVEMENT AREAS

The process areas requiring the most attention are summarized below in descending order of importance:

Process Area	Response	Problem	Solutions
1. Cleaning	Visual Cleanliness	Residues	Reduce oxidation with nitrogen Different paste Different reflow
2. Reflow	Solder Balls	Excessive	Nitrogen Standoffs Higher temps
3. Paste Deposit	Resolution	Smearing	Different paste
4. Standoff	Height	Inconsistency	PWB Feature
5. FPD Forming	Lead Skew	Excessive	Tighter control of material
6. FPD Tinning	Wick Height	Excessive	Nitrogen
7. FPD Placement	Lead Penetration	Insufficient	Change parameter

All of the above issues will be addressed before the start of EMPI program experiments. The material selections and equipment modifications described below should occur before the end of 1990.

Items 1 and 2 are being improved with the implementation of N2 in the IR oven. The current system is being improved with the elimination of leaks and will be documented as part of the standard reflow setup.

Items 1 and 3 are being improved by a change in the solder paste being used for reflow. A superior paste has already been identified after review of only 5 of 15 pastes. The additional pastes will be fully evaluated by the end of the year.

Item 4 is being improved with the change from an adhesive dot to a dry film standoff feature incorporated into the PWB fabrication. The tolerances of component height will be easier to meet with the application of a controlled thickness film product.

Item 5 is being improved with a tightening of the specification of the material coming into the forming die. The tolerance of incoming material will be tightened to minimize the amount of "pre-skew" allowed. The die seems to have a multiplying property in that the further a lead is skewed, the further it is skewed during forming.

Item 6 is being improved with the consistent use of nitrogen during tinning. The existing nitrogen purge above the pot will be quantified and evaluated by the end of the year.

Item 7 is being improved with the change in the placement pressure parameter of the robot.

Lessons Learned

The following items were identified as a direct result of running process capability studies on the equipment at TRW. The study followed the same methodology as outlined above, but examined only variables that were controllable within each workcell (intracell variables). Some of the items pertain to the generic performance of the study, while some of the items pertain to specific workcells and their capabilities.

1. <u>Cp alone is not sufficient for even a first approximation of process capability in many cases</u>. It was decided early in the study definition to ignore the difference between the values of the average process result and the average specification and concentrate only on the spread of the process as compared to the spread of the specification. The idea was that if the average of a process was not exactly midway between the upper and lower specification limits, it could be moved. An example would be a process temperature whose value was on the average 3° low which could simply be adjusted upward (without affecting the spread of temperatures). In this case, it would be the spread in temperature that would indicate the process capability since the average could simply be adjusted.

As it turns out, many processes do not have easily adjustable average results. An example is solder paste smear where the spread between the most and least smeared deposit is small but the average smear exceeds the specification limit. The resulting Cp based on the spread of responses would be good, but the actual process would need improvement.

2. <u>The method of calculating Cp (or Cpk) needs to be adjusted to include error terms</u>. It was decided early in the study definition to base the Cp calculation on the ratio of the specification limit spread divided by the process results spread created by manipulation of the variables. The assumption was that the process variation caused by the manipulation of the variables would correspond to the majority of the variation observed. The error was to be determined and reported separately. As it turns out, the combination of experimental, measurement, etc. error is usually the largest single contributor to process variation (at the variable levels tested). This means that the calculated CP's must be "de-rated" by a factor of 2 to 5. It will be much cleaner to include the error term directly in future calculations of Cp/Cpk.

3. The range of the variables evaluated during the experiments needs to be expanded where possible to minimize measurement error and obtain the "cleanest" understanding of the variable/response relationship. Many of the responses attributable to experimental error were equal to or greater than the responses that were variable-induced. This simply means that the control of the variables is tight enough that the process is not appreciably affected by the resulting variable range. This also means that the resulting variable/response relationship is difficult or impossible to determine because of the overshadowing of experimental error. This can be improved by intentionally increasing the variable range to make the resulting response large enough to become apparent.

4. The viscosity of the solder paste was found to be a poor indicator of printability of the paste. The viscosity of the paste was determined to be such a strong function of the temperature, test shear rate, and past history of the paste that any reading was essentially meaningless. A stencil with a test pattern was developed and is currently used to quantify the printability of the paste. See solder paste deposition report for further details.

5. The printability of the solder paste degrades with shelf life. Significant degradation in print definition has been noticed with unopened jars of paste with 2 to 3 months of shelf life remaining. TRW may need to establish a shelf life that is more conservative than the vendors. This decision must wait on the eventual selection of a paste vendor.

6. Nitrogen is a very critical (desirable) variable, affecting the component tinning, reflow and cleaning processes. It appears that the ability to purge oxygen out of the processing area during high temperature processes is very important to minimize the formation of oxidation and polymerization of flux. This has always been suspected, but has been finally demonstrated with the current set of experiments.

7. Most of the equipment had latent, subtle defects that were identified during the experimental process. These defects were only detected in a controlled experimental environment. Typical examples are the screen printer video probe inaccuracy (additional 0.002 in.) due to cable strain created by cable routing path and robot placement variation (additional 0.004 in.) due to a faulty camera calibration routine from the vendor. These problems are of the type that tend to increase the process variability since they are somewhat "hit or miss" and do not always show themselves on any given run. They only way to detect and solve them is with a systematic approach to each of the process responses.

8. The component forming, component placement, and reflow processes are very dependent on incoming material quality. In many cases, more than half of a given response variability could be traced back to material inconsistencies. For example, the reflowed solder joint appearance of one resistor type was smooth and shiny while another resistor type on the same PWB was rough and gritty. This result was repeated 16 times, and was independent of all other process variables.

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